H I L G A R D I A

A Journal of Agricultural Science Published by the California Agricultural Experiment Station

VOL. 29 NOVEMBER, 1959 No. 6

EFFECT OF GIBBERELLIN ON SEEDLESS *VITIS VINIFERA*[1,2]

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INTRODUCTION

THE STRIKING EFFECTS of gibberellin on many plants have been reviewed by Stowe and Yamaki (1957).[5] Experiments performed in 1957 (Weaver, 1957, 1958*a*, *b*; Weaver and McCune, 1958, 1959) showed that two seedless varieties of grape (*Vitis vinifera*) also responded markedly to gibberellin. Gibberellin treatment resulted in a high percentage set of very large berries in Black Corinth, and in large, elongated berries in Thompson Seedless sprayed after the berries had shattered. As a result of these striking responses, experiments were expanded in 1958 in an attempt to answer certain questions raised by previous work (Weaver and McCune, 1959). The studies were concerned with: the effect of gibberellin on growth of the individual berry; the effects of a wide range of concentrations; the influence of leaves as an avenue for entry of the compound into the fruit; the effect of time of treatment on response; the effects of treating portions of clusters or of berries; and elongation of cluster parts.

With Thompson Seedless, the question of whether gibberellin hastened ripening, and the influence of level of cropping on response to the compound were also considered. Finally, a study was made on response of Thompson Seedless to applications of gibberellin and 4-chlorophenoxyacetic acid (4-CPA) applied separately, at different dates, to the same vine, or as a mixture on one date.

In addition to the experiments with Black Corinth and Thompson Seedless, a spray experiment was performed on Black Monukka.

MATERIALS AND METHODS

Mature vines of Black Corinth, Thompson Seedless, and Black Monukka, in an irrigated vineyard at the University of California, Davis, were used. Black Corinth and Thompson Seedless were usually pruned to four canes,

[1] Submitted for publication January 12, 1959.

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[5] See "Literature Cited" for citations referred to in the text by author and date.

bearing from eight to 12 buds; Black Monukka was cordon-trained and spur-pruned.

Thompson Seedless were cluster-thinned to varying numbers of clusters per vine (Winkler, 1931). Where possible, an equal number of clusters were left on each cane, with all clusters being removed from the head of the vine. Berry thinning was accomplished by removing the apical half of the cluster (Winkler, 1931).

The procedure for measuring the amount of pull required to remove a pedicel from its berry has been previously described (Weaver and Winkler, 1952).

The water-soluble potassium salt of gibberellic acid containing 80 per cent active ingredient was supplied by Merck and Company. Concentrations are expressed in parts per million (ppm) on an acid-equivalent basis, and unless otherwise stated, Dreft (a proprietary compound of laural sulfate) was used as a wetting agent.

Sprays were applied with 3-gallon hand sprayers unless otherwise stated. The clusters and foliage were heavily sprayed until run-off. When necessary, cardboard shields were used to confine the spray to the intended area.

Average berry size was determined either by weighing 100 or 200 in duplicate, or by using calipers and reading to the nearest one-tenth millimeter. A Balling hydrometer was used to find percentage of total soluble solids in the juice. Total acidity was determined by diluting 10 ml of the juice to 50 ml with distilled water, and titrating with 0.133 N/NaOH, using phenolphthalein as an indicator. Results are expressed as gm of tartaric acid per 100 ml of juice—approximately the percentage of acid.

EXPERIMENTATION AND RESULTS

Black Corinth

Several experiments performed on Black Corinth indicated varying responses to gibberellin.

Berry Growth. On May 21, half of one vine (two canes) at full bloom was sprayed with gibberellin at 30 ppm. Full bloom was considered to be that point at which approximately 70 per cent of the calyptras had fallen. Two other canes on an adjacent vine were cane-girdled (Jacob, 1931). On date of treatment, the average diameter of 20 berries was 1.1 mm. On May 26 and May 29, in each treatment, the diameters of 20 berries selected at random were measured. On June 2, when the berries were large enough to be marked by a spot of India ink, 20 berries were marked in each treatment. Marked berries were measured as soon as the ink had dried, and at intervals thereafter until August 1 (fig. 1). Berries grew very rapidly until June 2, and had attained maximum diameter by about July 23. Although berries from the vines treated with gibberellin were larger than those from the cane-girdled vines within eight days, the growth curves for both were similar. Since gibberellin stimulates growth in length, measurements of length of berry would probably have shown greater differences between girdled and sprayed berries.

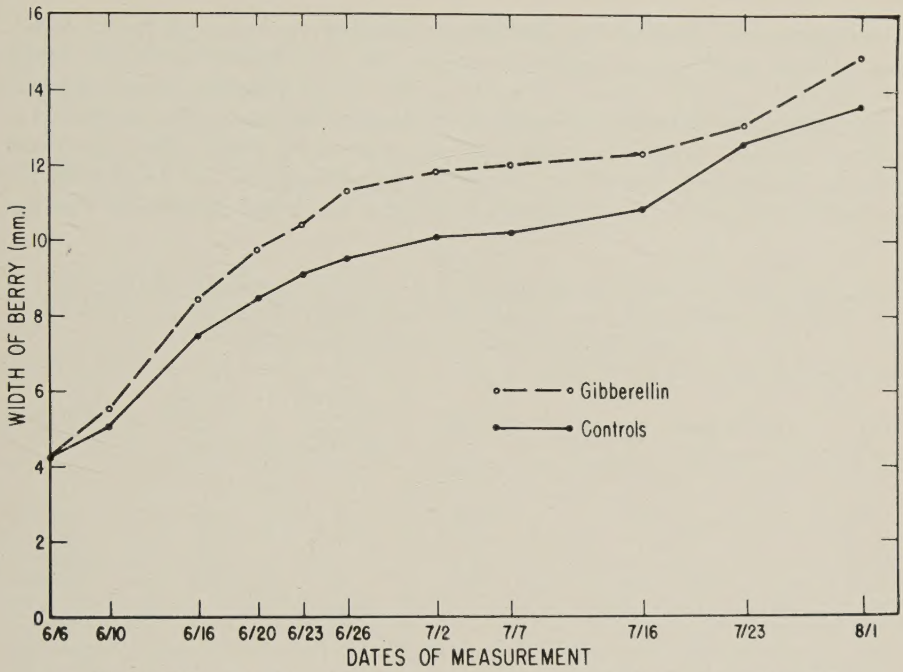

Fig. 1. Effect of gibberellin at 30 ppm, applied at full bloom, on growth of Black Corinth berries.

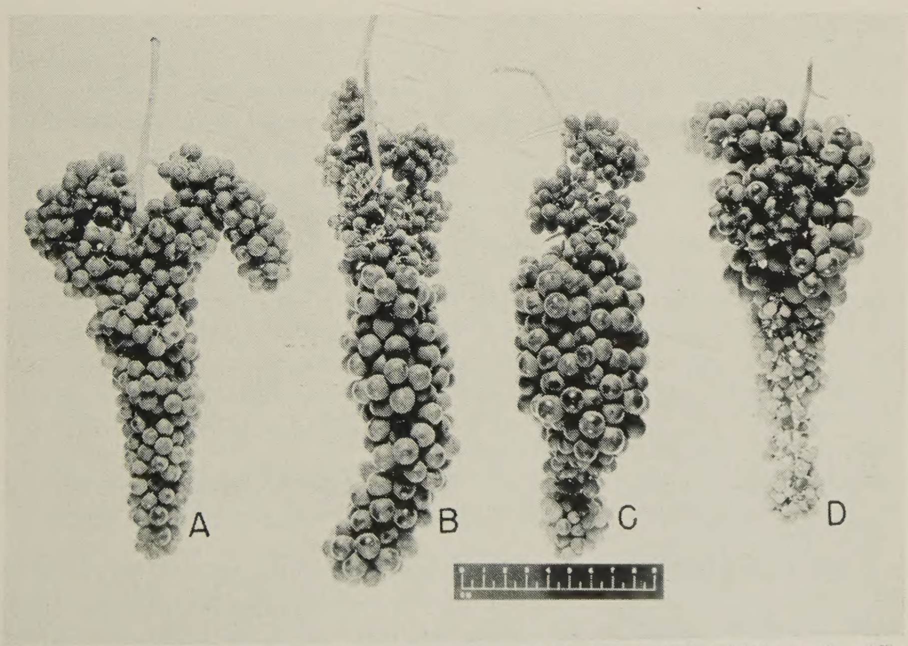

Fig. 2. Black Corinth clusters 55 days after the apical portion (B), middle portion (C), or basal portion (D) was treated with gibberellin at a concentration of 100 ppm. (A) is untreated control. Note that berries have enlarged only where gibberellin was applied. (Photographed August 5, 1958.)

Treatment of Portions of Clusters or Berries. In one experiment, treatments were made on ungirdled vines on June 11, following bloom, when the berries were 4 to 5 mm in diameter. The apical portions of five clusters were dipped in gibberellin at a concentration of 100 ppm. The middle portions of another series of clusters were sprayed with gibberellin, by means of a De Vilbiss No. 15 atomizer sprayer, while the apical and basal portions were protected with waterproof plastic sheets. The basal portions of another series of clusters were similarly sprayed. One set of clusters served as controls.

TABLE 1
DATA AT HARVEST (AUGUST 5) FOR BLACK CORINTH DIPPED IN GIBBERELLIN AT 25 PPM ON VARIOUS DATES
(Figures are averages of 10 replicate clusters.)

Time of dipping	Length of cluster	Length of second lateral from base	Number of berries per cluster*	Weight per berry
	cm	*cm*		*gm*
Not dipped	22.8	4.1	562	0.26
May 14	23.5	4.6	237	0.77
May 19	25.2	4.8	249	0.97
May 23	23.0	3.9	217	0.66
L.S.D. at 5 per cent	....	....	95	....

* Small shot berries that failed to soften or color were not counted.

Clusters were harvested on August 5. The controls had a high percentage set of small berries, and berries on the treated clusters were enlarged only where the gibberellin had been applied (fig. 2). Little or no translocation to untreated areas was evident as judged by enlargement of berries.

In another experiment, sufficient gibberellin was added to India ink to make a solution of 1,000 ppm. Small portions of 10 berries were painted with the solution on June 11, the ink serving to mark the application spot. On August 5, it was noted that only the painted berries had enlarged. Their average diameter was 11.4 mm, while that of 10 adjacent, unpainted berries was 8.7 mm. The enlarged, treated berries were symmetrical, indicating that the gibberellin diffused uniformly throughout the berry. This experiment also shows that India ink does not inactivate gibberellin, and that it is relatively nontoxic to the plant. When Sheaffer's blue-black Skrip was used for marking, it proved extremely phytotoxic.

These experiments demonstrate that little or none of the gibberellin applied to one berry moves to adjacent berries although it is readily transported within a given berry.

Effect of Stage of Development of Clusters. Only one cluster was used per shoot; the others were removed before treatment. On May 14, about one week before the inception of bloom, 10 clusters were dipped in gibberellin at a concentration of 25 ppm. Another set was similarly treated on May 19

when about 20 per cent of the calyptras had fallen, and a final series was dipped on May 23 after all calyptras had fallen. One series of clusters was used as untreated controls.

Fruit was harvested on August 5. At that time the controls had over twice as many berries as the treated clusters (table 1).

All dipped clusters had large, elongated berries, but clusters were loose. Length of cluster and of second lateral from the base was usually slightly

TABLE 2

DATA AT HARVEST (AUGUST 5) FOR BLACK CORINTH SPRAYED WITH GIBBERELLIN OR 4-CHLOROPHENOXYACETIC ACID (4-CPA) ON MAY 26

(Figures are averages of three replicate vines.)

Condition of vine	Treatment		Length per berry	Width per berry	Length-to-width ratio	Weight per berry	Degrees Balling	Total acid, per cent tartaric
	Concentration of gibberellin	Concentration of 4-CPA						
	ppm	*ppm*	*mm**	*mm**		*gm*		
Not girdled	0	..	8.8	8.3	1.06	0.32	19.7	1.26
Girdled	0	..	11.6	10.6	1.09	0.69	15.7	1.38
Not girdled	1	..	10.8	10.0	1.08	0.67	19.3	1.14
Not girdled	2½	..	11.8	10.4	1.13	0.80	18.8	1.12
Not girdled	5	..	13.6	11.2	1.21	0.96	17.0	1.20
Not girdled	10	..	14.5	11.8	1.23	1.03	15.3	1.15
Not girdled	20	..	14.5	11.6	1.25	1.11	18.3	1.12
Not girdled	50	..	14.5	11.9	1.23	1.06	16.4	1.12
Not girdled	100	..	15.0	12.4	1.21	1.27	16.9	1.12
Not girdled	..	30	10.8	10.1	1.07	0.71	15.0	1.15
L.S.D. at 5 per cent	..	..	1.0	0.6	....	....	....	....

* Average of 10 berries.

increased by gibberellin. The largest berries resulted from the dipping on May 19. It is of interest that gibberellin applied even before calyptras fell (May 14) resulted in large berries.

Effect of Sprays of Varying Concentrations. Vines were treated on May 26, shortly after the bloom stage, three vines per treatment. Gibberellin was applied at 0, 1, 2.5, 5, 10, 20, 50, or 100 ppm. As a basis for comparison, three vines were sprayed with 4-chlorophenoxyacetic acid (4-CPA) at 30 ppm since this compound is used commercially in California to produce set in Black Corinth (Weaver, 1956). One series of vines was trunk-girdled but unsprayed; another, ungirdled, unsprayed series served as controls.

Half the fruit (two canes from each vine) was harvested on August 5 (fig. 3). Berries sprayed with gibberellin at 1 ppm were enlarged, but the clusters were straggly. Gibberellin in the range from 2.5 to 100 ppm resulted in a good set of large, elongated berries, while girdling or spraying with 4-CPA produced a high percentage set of almost round berries. No hard seeds were found in any treatment.

The data (table 2, figs. 3, 4) indicate that length, width, length-to-width ratio, and weight per berry usually increased progressively as the concentra-

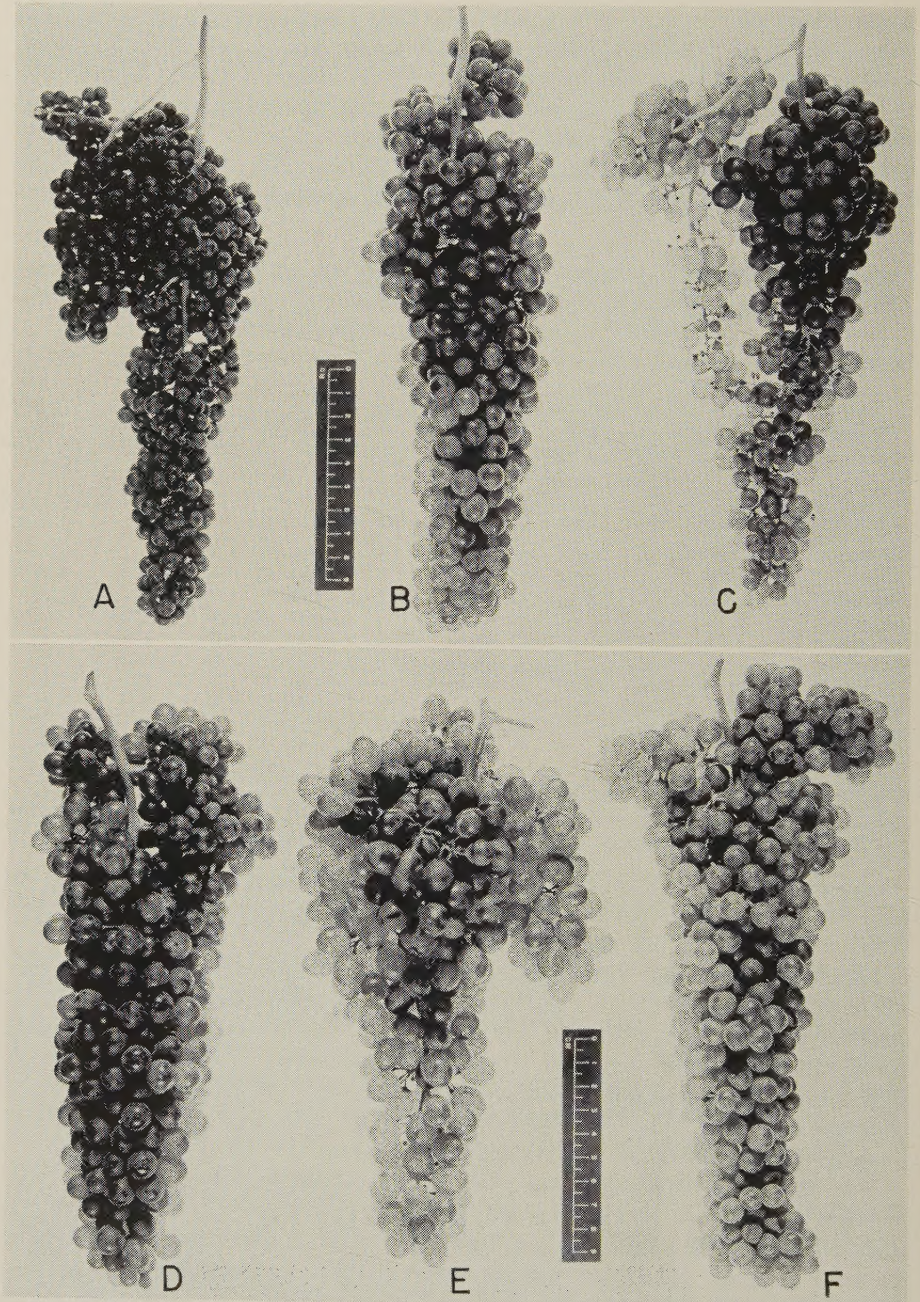

Fig. 3. Black Corinth grapes 71 days after being sprayed with gibberellin at 1 (C), 5 (D), or 100 (E) ppm. (A) control; (B) girdled but unsprayed; (F) sprayed with 4-chlorophenoxyacetic acid (4-CPA) at 30 ppm. Girdling (B) and 4-CPA (F) resulted in a high percentage set of round berries. Gibberellin at 1 ppm (C) resulted in a straggly cluster, but the compound at 5 (D) and at 100 ppm (E) resulted in a set of large berries and a loose cluster. (Photographed August 6, 1958.)

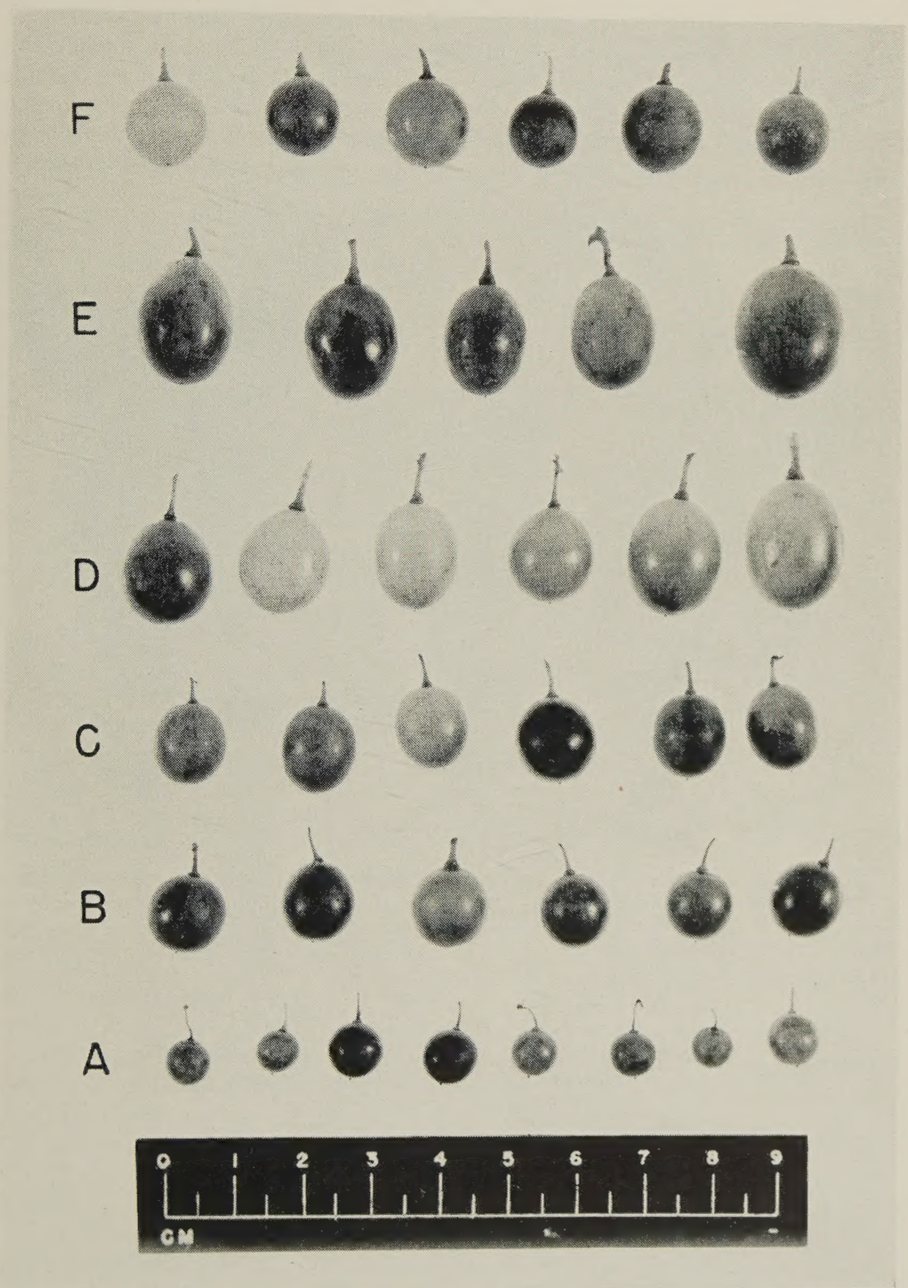

Fig. 4. Black Corinth berries at harvest, 71 days after being sprayed with gibberellin or 4-chlorophenoxyacetic acid (4-CPA). (A) ungirdled, unsprayed; (B) girdled but not sprayed; gibberellin at 1 (C), 10 (D), or 100 ppm (E); 4-CPA at 30 ppm (F). Note that girdling (B) and 4-CPA (F) resulted in small, round berries and that gibberellin at 10 (D) or 100 ppm (E) produced large, elongated berries. (Photographed August 6, 1958.)

tion of gibberellin was increased. Girdled berries and those sprayed with 4-CPA were not much longer than they were wide. Balling readings were erratic although girdling and 4-CPA spray, with one exception, resulted in the lowest readings.

Influence of Foliar Applications on Clusters. On May 26, after the berries were set, 10 clusters on each of two ungirdled vines were inclosed in water-

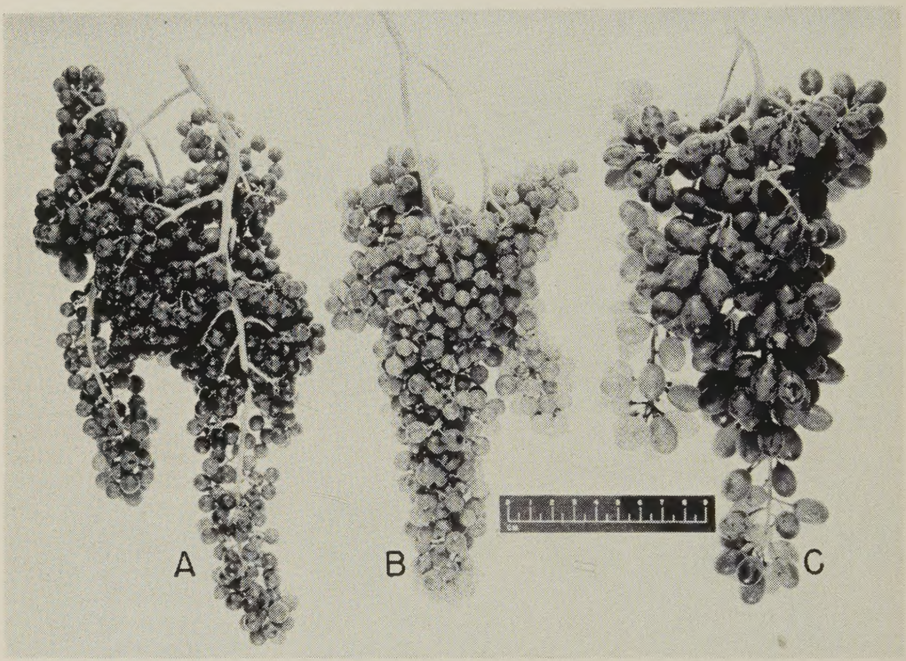

Fig. 5. Black Corinth clusters at harvest, from vines sprayed with gibberellin at 25 ppm. (B) was enclosed in a waterproof plastic bag at time of spraying, but (C) was heavily sprayed. (A) cluster from ungirdled, unsprayed vine. Note little or no response of bagged cluster (B) to the compound, but that (C) has produced very large, elongated berries. (Photographed August 5, 1958.)

TABLE 3

DATA AT HARVEST (AUGUST 25) FOR UNGIRDLED BLACK CORINTH GRAPES SPRAYED WITH GIBBERELLIN AT 25 PPM

(Figures are averages of 20 replicate clusters.)

Treatment	Weight per cluster	Weight per berry
	gm	*gm*
Unsprayed	143	0.29
Leaves sprayed, clusters sprayed	389	0.93
Leaves sprayed, clusters bagged	188	0.37
L.S.D. at 5 per cent	96	0.12

proof plastic bags. The entire vines, including the unbagged clusters, were heavily sprayed with gibberellin at 25 ppm. The bags were removed after the spray had dried. Clusters from ungirdled, unsprayed vines served as controls. The clusters were harvested on August 25. Berries from ungirdled, unsprayed vines had a high percentage set of small berries (table 3, fig. 5). Bagged clusters from sprayed vines appeared in general like those from the unsprayed vines, although cluster and berry weights were slightly higher. A few of these clusters had many large, elongated berries, others had only a few. Sprayed clusters had enlarged, elongated berries and a high cluster weight. These data indicate that only a small amount of gibberellin enters the fruit through the leaves, and that, for maximum response, the spray should contact the fruit.

Thompson Seedless

Elongation of Young Cluster. The purpose was to determine which portion of a young Thompson Seedless cluster is most responsive to gibberellin. On April 22, when shoots were about 10 to 12 inches long, and the clusters about 4 inches long, 10 clusters were dipped in gibberellin at 100 ppm. After the spray dried, India ink was applied, with a brush, on one side of the rachis at a point half way from the apex to the basal lateral. Ten undipped clusters were similarly marked. Length of peduncle, distance from basal branch to ink mark, and from ink mark to apex were measured at time of treatment and at various intervals thereafter. It was necessary to remake the ink marks on two subsequent dates after the beginning of the experiment.

The results (figs. 6, 7) show that all portions of the cluster treated with gibberellin increased rapidly in length, and that almost maximum length was reached early in June. Control parts never attained the length of treated portions. The percentage increase in length was greatest in the apical portion and least in the basal (peduncle).

Spraying of Entire Vines at Prebloom Stages. Vines were cluster-thinned to 20 per vine, but were not berry-thinned. On April 15, when shoots were 2½ to 4 inches long and clusters about ½ inch long, vines were sprayed with gibberellin at 0, 10, 25, or 50 ppm, five vines per treatment. A second series of vines was similarly sprayed on April 28 when many shoots were 10 to 12 inches long, and clusters 3 to 5 inches long, and a third series was treated on May 9, when shoots varied from 18 to 36 inches in length and clusters from 5 to 7 inches. A final treatment was made on May 19 a few days before blooming began. A randomized split-plot arrangement was used.

Flowering was hastened by the first three applications. For example, on May 19 about 1, 3, 5, and 20 per cent of the calyptras had fallen from clusters sprayed on April 28 with gibberellin at 0, 10, 25, or 50 ppm, respectively.

Fruit was harvested on August 25. For length measurements, 10 clusters were taken from each vine. Length of cluster was increased by the second spraying (table 4). Length of peduncle, pedicel, and second lateral from base was usually increased by gibberellin. Weight of fruit per vine was sometimes decreased, probably as a result of formation of shot berries. Of the four treatments in which crop level could be eliminated as a factor, only

two (10 or 25 ppm sprayed on May 9) showed a significant increase in percentage of total soluble solids as a result of the compound.

Repeated Application at Prebloom and at Shatter Stages. The purpose was to apply gibberellin at a prebloom stage, to elongate cluster parts, and

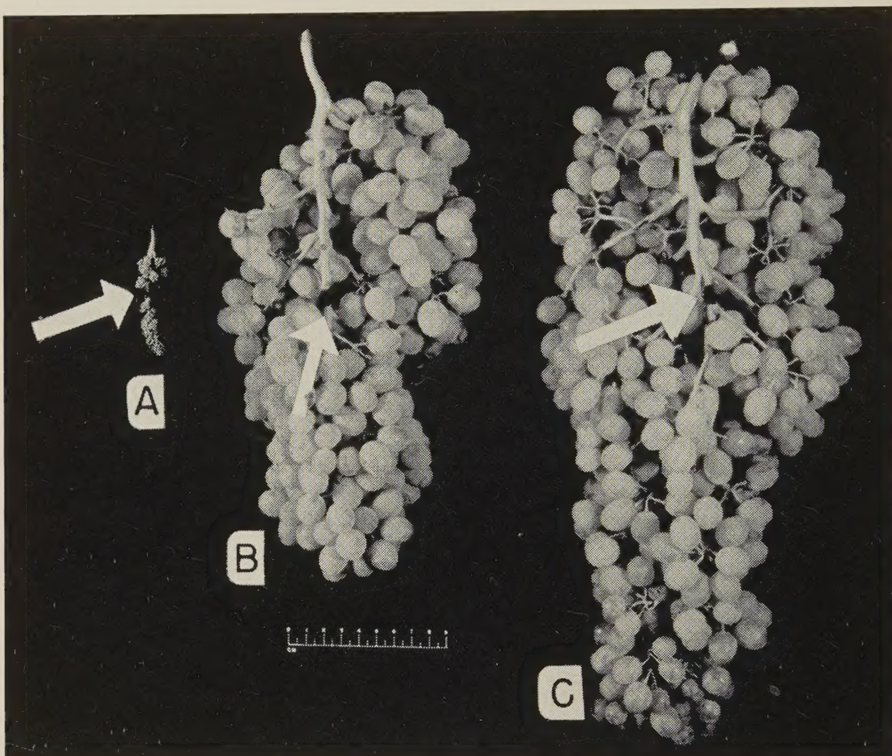

Fig. 6. Development of Thompson Seedless clusters as affected by being dipped in gibberellin at 100 ppm. Undipped clusters at time of treatment on April 22, 1958 (A), and at harvest on August 29 (B). Dipped clusters at harvest (C). Note that greatest elongation in treated cluster (C) occurred in apical portion. Arrows point to ink marks used in measurements. (Photographed August 29, 1958.)

then to repeat the application or to girdle at the time of berry shatter to determine whether berry size could be increased. Two vines bearing about 20 clusters each (not berry-thinned) were sprayed on April 28 with gibberellin at 50 ppm. On June 11, after the shatter of berries, clusters on half of one vine were dipped in gibberellin at 50 ppm. Two canes on the other vine (half the vine) were cane-girdled. Fruit was harvested on August 25. The results show that both dipping in gibberellin and girdling on June 11 greatly increased berry size. The average weight per berry for fruit from parts of vines sprayed on April 28 but not treated on June 11 was 1.38 gm. The average weights per berry for portions of vines sprayed on April 28 and

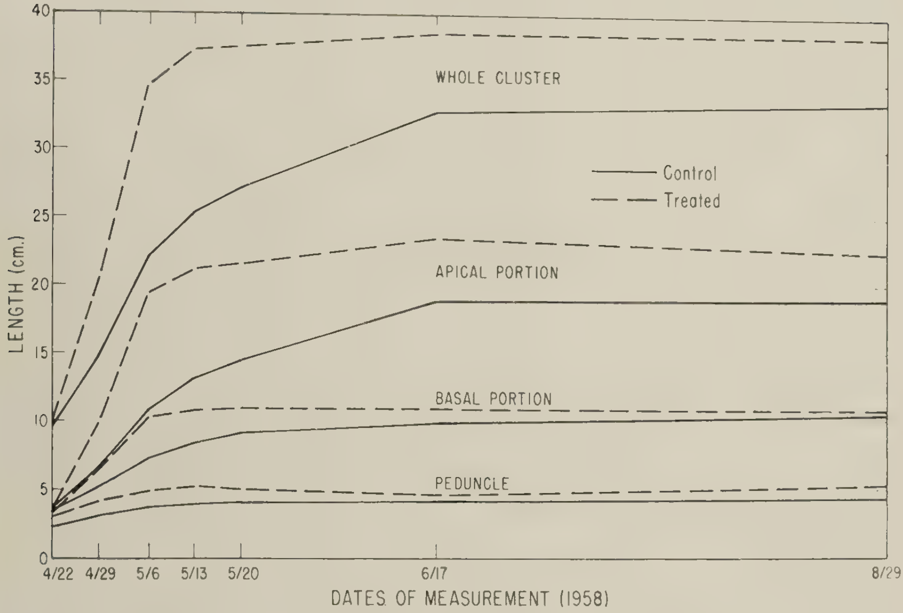

Fig. 7. Elongation of peduncle, basal, and apical parts of cluster of Thompson Seedless after being dipped in gibberellin at 100 ppm on April 22 (broken lines). Solid line, untreated.

Fig. 8. Thompson Seedless grapes at harvest (August 25), sprayed with gibberellin at 50 ppm on April 28 to elongate clusters. (B) girdled on June 11 after shatter of berries; (C) dipped in gibberellin at 50 ppm on June 11. No additional treatment was given (A). Note that both girdling (B) and dipping in gibberellin (C) on June 11 increased berry size. (Photographed August 29, 1958.)

TABLE 4

DATA AT HARVEST (AUGUST 25) FOR THOMPSON SEEDLESS CLUSTERS SPRAYED ON APRIL 15, APRIL 28, MAY 9, OR MAY 19, WITH GIBBERELLIN AT VARIOUS CONCENTRATIONS

(Lengths are averages of 10 replicate clusters, and other measurements averages of five replicate vines.)

Treatment, concentration of gibberellin	Length of cluster	Length of peduncle	Length of second lateral from base	Length pedicel	Weight fruit per vine	Weight per berry	Degrees Balling	Total acid, per cent tartaric
				Sprayed April 15				
ppm	*cm*	*cm*	*cm*	*mm*	*lb*	*gm*		
0	31.6	4.1	11.0	6.5	41.0	1.77	17.6	0.83
10	....	....	....	....	32.5	1.73	17.4	0.79
25	....	....	....	....	32.0	1.69	18.3	0.80
50	30.5	5.0	11.8	7.0	33.0	1.76	17.6	0.84
				Sprayed April 28				
0	30.6	4.2	10.0	6.9	40.7	1.87	16.8	0.78
10	....	....	....	....	36.1	1.80	18.0	0.78
25	....	....	....	....	40.6	1.85	16.7	0.79
50	34.1	4.8	12.7	7.1	33.9	1.61	17.2	0.76
				Sprayed May 9				
0	32.2	4.2	12.1	6.9	36.0	1.76	16.4	0.82
10	....	....	....	....	36.3	1.91	17.7	0.78
25	....	....	....	....	33.7	1.93	17.9	0.80
50	31.8	4.6	10.8	7.5	32.1	1.95	18.1	0.77
				Sprayed May 19				
0	27.7	4.2	9.7	6.9	35.5	1.99	17.6	0.77
10	....	....	....	....	35.4	1.90	17.9	0.75
25	....	....	....	....	28.5	2.03	20.2	0.74
50	30.2	4.6	10.9	7.8	26.0	2.12	19.6	0.72
(1)*	N.S.	0.4	0.5	0.2	3.1	N.S.	0.8	N.S.
(2)†	1.7	N.S.	N.S.	0.5	N.S.	0.10	1.0	N.S.

* L.S.D. at 5 per cent for concentrations at a given date of spraying.
† L.S.D. at 5 per cent for different spraying dates at a given concentration.

then dipped or girdled on June 11 were 2.46 and 2.48 gm, respectively (fig. 8).

Berry Growth. On June 6 two vines were sprayed with gibberellin at a concentration of 50 ppm. After the spray had dried, 10 berries on each vine were marked with a spot of India ink. Ten berries on each of two unsprayed vines were similarly marked. The diameters of the berries were measured immediately after the ink had dried, and at various intervals thereafter (fig. 9). Soon after treatment, the berries sprayed with gibberellin were larger

than the controls, and remained larger throughout the season. When the cumulative growth increments were plotted, both treated and control berries produced a double sigmoid curve. Greater differences would probably have been obtained between controls and treated vines if length measurements had been made since gibberellin greatly stimulates elongation. However, this is difficult to do with attached berries.

Treatment of Portions of Clusters. After berry shatter was completed on June 11, when the remaining berries were about 5 mm in diameter, the

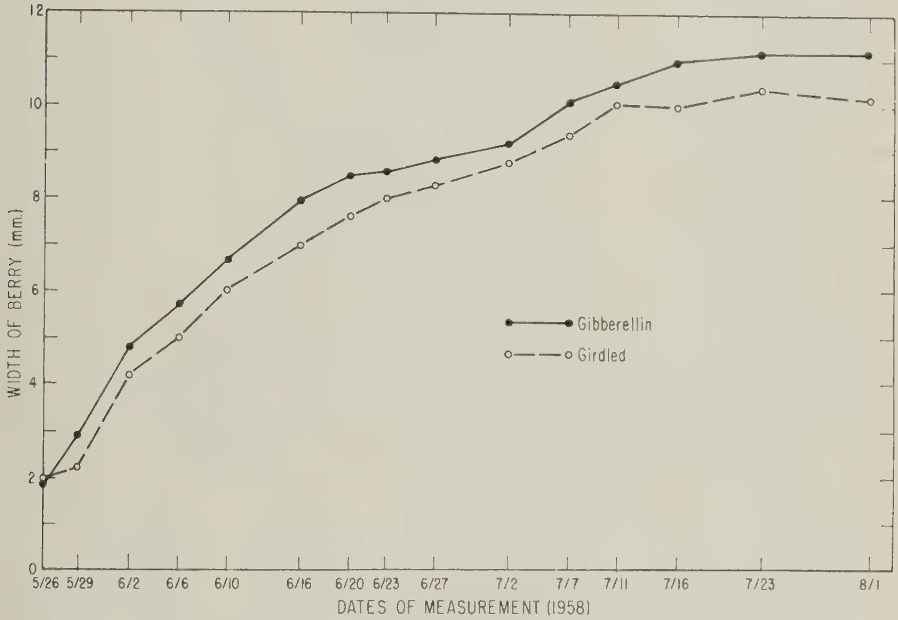

Fig. 9. Growth curve of berries of untreated Thompson Seedless and of berries from vines sprayed with gibberellin at 50 ppm on June 6.

apical portions of five clusters were sprayed with gibberellin at 100 ppm, with a No. 15 De Vilbiss atomizer sprayer. The basal portions of another set of clusters were sprayed, and in a third series the bases of three laterals were marked with India ink. After the ink had dried, the laterals were sprayed with gibberellin. During spraying, cluster parts not intended to be sprayed were wrapped in waterproof plastic sheets. At harvest on August 29, it was evident that only sprayed berries had enlarged (fig. 10), indicating there had been little or no translocation of gibberellin. Clusters on which apical or basal portions were treated were divided into treated and untreated parts, and degree Balling and percentage of total acid were determined. The sprayed portion had the lower Balling reading and, with one exception, higher percentage of acid regardless of whether the apical or basal portion was treated (table 5). The lower Balling reading in the treated portions may be ascribed to the greater weight of fruit, but it does not explain

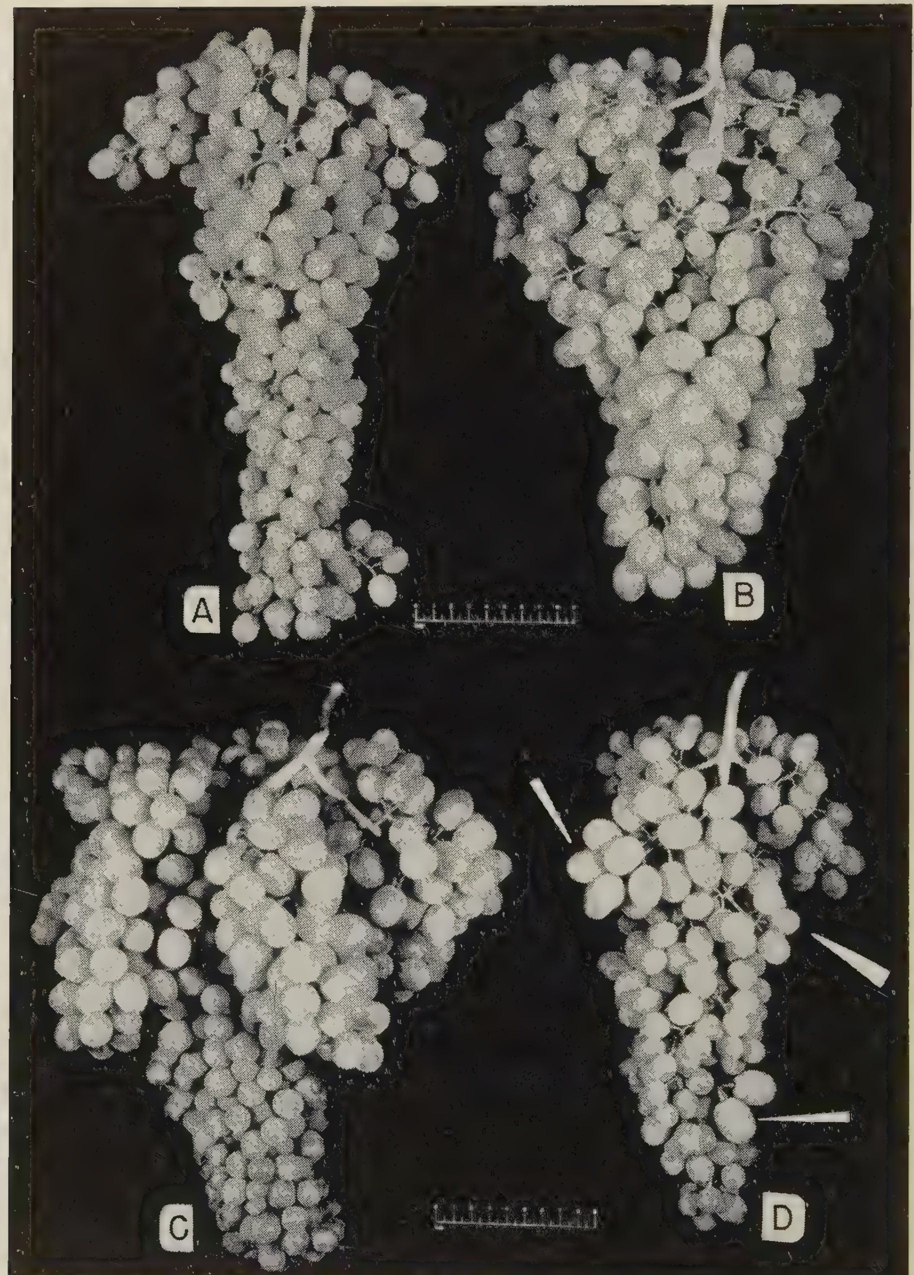

Fig. 10. Thompson Seedless clusters 79 days after apical (B) or basal (C) portions were treated with gibberellin at 100 ppm. On cluster (D), three branches (see arrows) were sprayed. (A) is the control. In all cases, only the treated portions responded to the gibberellin. (Photographed August 29, 1958.)

why the sugars were not evenly distributed throughout the cluster. Sprayed laterals also had a lower Balling reading than did the adjacent unsprayed branches.

Other experiments were performed to determine whether the effects of gibberellin could be localized within a berry near the site of application. On June 11, gibberellin at 100 ppm was placed on the apical portions of five berries, around the basal portions of another series, and on the sides of a third series. Five untreated berries served as controls. All were marked with India ink for identification. When final observations were made on

TABLE 5

EFFECT ON MATURATION OF TREATING PORTIONS OF THOMPSON SEEDLESS CLUSTERS WITH GIBBERELLIN AT 100 PPM

Portion of cluster treated	Degrees Balling		Total acid, per cent tartaric	
	Apical	Basal	Apical	Basal
Apical	15.9	17.9	0.69	0.74
Basal	17.5	15.5	0.76	0.95

August 29, all treated berries had enlarged and elongated symmetrically. Since no treatment resulted in an abnormally shaped berry, it is indicated that gibberellin moved throughout the berry.

Wooden toothpicks were soaked overnight in gibberellin at 1,000 ppm, dried, and inserted into or through berries on June 11. Untreated toothpicks were similarly inserted into and through other berries. On August 29 it was noted that gibberellin-treated berries were larger than, but otherwise similar to controls. When toothpicks were inserted through the berries, a flattening out of the berry occurred.

These experiments demonstrate that gibberellin readily moves within a treated berry, but that little or none moves from one berry to another.

Effect of Various Concentrations. The purpose was to determine degree of response of berries to various concentrations of gibberellin applied at the proper time for girdling. The combined effect of gibberellin and girdling was also studied. Vines were thinned to 20 clusters per vine, and berry-thinned on June 6 after berry shatter had occurred (Winkler, 1931). Vines were sprayed with various concentrations of gibberellin, and/or trunk-girdled on the same date (table 6). Four vines were used per treatment, except for the application of gibberellin at 1,000 ppm both with and without trunk-girdling, in which cases one vine was used.

Fruit was harvested on August 29. Controls had berries larger than those obtained at Davis in 1957 (Weaver, 1958*a*, *b*). The data (table 6) demonstrate the elongating effect produced by gibberellin on both ungirdled and girdled berries, and indicate that even 1 ppm of this compound increases size of berry. Although the data are erratic, the general trend is for higher concentrations to produce larger berries (table 6, figs. 11, 12). However, gibberellin at 1,000 ppm produced some smaller berries and injured many by

producing a corkiness on them (fig. 13). Cluster frameworks were very brittle in this treatment. Pedicels on treated clusters were slightly thickened at the lower concentrations, and were two to three times as thick on clusters sprayed at 1,000 ppm. Balling readings showed no definite trends except for a depression at the higher concentrations, probably as a result of a

TABLE 6

DATA AT HARVEST (AUGUST 29) FOR THOMPSON SEEDLESS SPRAYED WITH GIBBERELLIN AND/OR TRUNK-GIRDLED ON JUNE 6

(Figures are averages of four replicates except for the 1,000-ppm treatments.)

Treatment: Condition of vine	Treatment: Concentration of gibberellin	Length per berry*	Width per berry*	Length-to-width ratio	Weight per berry	Degrees Balling	Total acid, per cent tartaric
	ppm	*mm*	*mm*		*gm*		
Not girdled	0	17.7	13.2	1.34	1.93	20.5	0.69
Not girdled	1	....	....	....	2.45	20.5	0.69
Not girdled	2.5	....	....	....	2.14	21.0	0.66
Not girdled	5	....	....	....	2.47	20.5	0.68
Not girdled	10	....	....	....	2.24	19.7	0.71
Not girdled	20	....	....	....	2.44	21.4	0.70
Not girdled	50	21.1	15.1	1.40	2.81	17.3	0.70
Not girdled	100	....	....	....	3.09	17.0	0.70
Not girdled	1,000	....	....	....	2.91	18.9	0.64
Girdled	0	18.3	14.3	1.28	2.42	17.0	0.72
Girdled	10	....	....	....	2.64	16.3	0.78
Girdled	50	24.1	16.9	1.43	3.71	15.7	0.75
Girdled	1,000	....	....	....	3.97	15.2	0.69
(1)†	....	....	....	....	0.47	....	....
(2)‡	....	....	....	....	0.90	....	....

* Linear measurements are averages of 20 berries.
† L.S.D. at 5 per cent for nongirdled treatments except for 1,000 ppm.
‡ L.S.D. at 5 per cent for girdled treatments, except for 1,000 ppm.

heavier crop. No definite trends were observed in the percentage of total acid. The largest berries were produced by combined girdling and gibberellin (table 6, fig. 12).

Neither foliage nor shoots was injured by any concentration of gibberellin used.

Effect of Time of Treatment to Obtain Maximum Berry Size. On June 2, when shatter was almost complete, vines were cluster-thinned to 20 clusters per vine, and berry-thinned. Four vines were then sprayed with gibberellin at 50 ppm. Other series of vines were similarly sprayed on later dates (table 7). Fruit was harvested on August 28. The results show that the largest berries were produced by the sprayings on June 2 and June 7, and that later sprayings produced progressively smaller berries (fig. 14). However, berries from the last three sprayings were not significantly larger than those not sprayed, and those from vines sprayed on July 29 were only slightly larger than the unsprayed berries. Balling readings were depressed by most gibberellin treatments.

Fig. 11. Thompson Seedless clusters from ungirdled vines 84 days after being sprayed with gibberellin at 20 (B), 100 (C), or 1,000 ppm (D). (A) is unsprayed control. Note that berry size and elongation increase with higher concentrations of compound. Slight injury to berries resulted from gibberellin at 1,000 ppm. (Photographed August 29, 1958.)

Influence of Level of Crop on Response to Gibberellin. On June 6, vines were thinned to 16, 32, or 48 clusters per vine. Remaining clusters were berry-thinned. One series of vines at each crop level was sprayed on June 6 with gibberellin at 20 ppm. Other vines were left unsprayed. There were three replicate vines per treatment.

Fig. 12. Thompson Seedless clusters from girdled vines 84 days after being sprayed with gibberellin at 10 (B), 50 (C), or 1,000 ppm (D). (A) is unsprayed control. Note that very large berries resulted from gibberellin applied at 10 (B) or 50 ppm (C) and that injury occurred at 1,000 ppm (D). (Photographed August 29, 1958.)

Fruit was harvested on September 4. At all crop levels, low, medium, or high, sprayed berries appeared more elongated than unsprayed checks. The data (table 8) indicate that larger berries were produced at all crop levels by treatment with gibberellin. Perhaps even the vines bearing 70 pounds of fruit were not overloaded or, what is less likely, perhaps even on over-

Fig. 13. Berries of ungirdled Thompson Seedless 84 days after vines were sprayed with gibberellin at 1,000 ppm (B). (A) are unsprayed controls. Note that treated berries (B) show varying degrees of corkiness. (Photographed August 29, 1958.)

TABLE 7

DATA AT HARVEST (AUGUST 28) FOR THOMPSON SEEDLESS GRAPES FROM UNGIRDLED VINES SPRAYED AFTER BERRY SHATTER ON JUNE 2, AND AT VARIOUS LATER DATES, WITH GIBBERELLIN AT 50 PPM

Date of spraying	Stage of development	Weight per berry	Degrees Balling	Total acid, per cent tartaric
		gm		
Not sprayed		1.96	21.6	0.60
June 2	Shatter of berries almost completed	3.25	18.6	0.61
June 7	Berries 4–5 mm in diameter	3.47	18.7	0.58
June 16		2.89	16.3	0.75
June 23	Berries about 5/16″ in diameter	2.45	16.4	0.79
June 30	Berries 5/16–3/8″ in diameter	2.34	16.0	0.79
July 29	Degrees Balling about 12	2.01	19.5	0.64
L.S.D. at 5 per cent		0.60	2.2	0.12

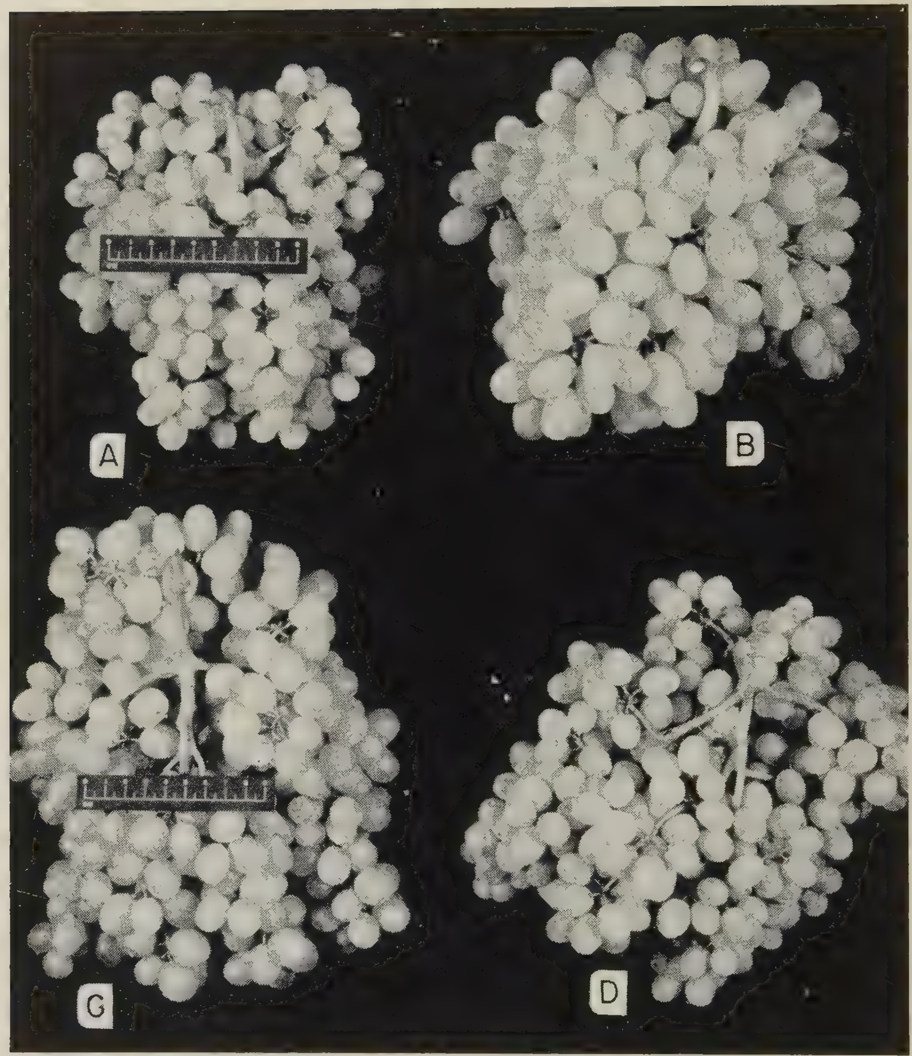

Fig. 14. Clusters of Thompson Seedless at harvest (August 28, 1958) after being sprayed with gibberellin at 50 ppm on June 2 (B), June 16 (C), or June 30 (D). (A) is unsprayed control. Note that size of berries decreased as time of spraying was delayed. (Photographed September 2, 1958.)

cropped vines, berries will respond to the compound. Percentage of total soluble solids decreased, and percentage of acid usually increased with higher crop levels.

Influence of Gibberellin on Rate of Ripening. This experiment was designed to eliminate differences in crop levels in the different treatments so that any differences in maturation could be attributed to gibberellin.

TABLE 8

INFLUENCE OF CROP LEVEL IN THOMPSON SEEDLESS ON RESPONSE TO GIBBERELLIN AT 20 PPM

(Figures are averages of three replicate vines.)

Thinning and spray treatment	Weight of crop per vine	Weight per berry	Degrees Balling	Total acid, per cent tartaric
	lb	*gm*		
16 clusters per vine, not sprayed	31.5	2.24	20.0	0.70
32 clusters per vine, not sprayed	51.8	1.84	19.2	0.72
48 clusters per vine, not sprayed	70.7	1.80	15.1	0.77
16 clusters per vine, sprayed	46.7	2.92	19 7	0.72
32 clusters per vine, sprayed	53.2	2.63	17.1	0.70
48 clusters per vine, sprayed	82.5	2.34	14.3	0.81
(1)*	10.5	N.S.	1.7	
(2)†	N.S.	0.38	0.4	

* L.S.D. at 5 per cent among unsprayed or sprayed.
† L.S.D. at 5 per cent between unsprayed and sprayed at a given number of clusters.

TABLE 9

EFFECT OF GIBBERELLIN ON MATURATION OF THOMPSON SEEDLESS GRAPES

(Figures are averages of four replicate vines.)

Treatment	Number of clusters per vine retained at thinning	Weight of fruit per vine	Weight per berry	Degrees Balling	Total acid, per cent tartaric
		lb	*gm*		
Not girdled, not sprayed	28	31.0	1.88	18.9	0.76
Not girdled, gibberellin at 20 ppm	16	27.0	2.65	18.8	0.77
Not girdled, gibberellin at 50 ppm	14	30.5	2.52	17.9	0.77
Girdled, not sprayed	20	32.5	2.46	17.6	0.83
L.S.D. at 5 per cent	..	N.S.	0.24	N.S.	N.S.

Data obtained in 1957 (Weaver and McCune, 1958) were used in determining the amount of thinning with the hope that the resulting crops would be about equal. On June 4, vines were cluster-thinned to varying numbers of clusters (table 9), and the remaining clusters were berry-thinned. On the following day, trunk girdling and spray applications of gibberellin were performed, four vines per treatment. Fruit was harvested on August 22 (table 9). The crops were about equal except that vines sprayed with gibberellin at 20 ppm had a smaller crop. Gibberellin had no significant effect on maturation as measured by the Balling readings.

Influence on Fruit of Gibberellin Absorbed by Leaves. On June 3, vines were thinned to 20 clusters per vine, and berry-thinned. The clusters in one lot were enclosed in waterproof plastic bags before the entire vine was sprayed with 25 ppm of gibberellin. After the spray had dried, the bags

were removed. The clusters on another lot of unsprayed vines were treated by dipping in solutions of gibberellin at 25 ppm. In another lot, the foliage was sprayed and the clusters were dipped, while still another lot served as the untreated controls. There were four replicate vines per treatment. Fruit was harvested on August 28.

TABLE 10

EFFECT OF GIBBERELLIN AT 25 PPM APPLIED TO FOLIAGE AND/OR FRUIT OF THOMPSON SEEDLESS GRAPES

(Figures are averages of four replicate vines.)

Treatment	Weight per berry	Degrees Balling	Total acid, per cent tartaric
	gm		
Control	1.86	21.4	0.67
Leaves sprayed, clusters bagged	2.18	19.4	0.68
Leaves not sprayed, clusters dipped	2.44	21.4	0.65
Leaves sprayed, clusters dipped	3.06	19.3	0.67
L.S.D. at 5 per cent	0.59	N.S.	N.S.

TABLE 11

EFFECT OF GIBBERELLIN AT 50 PPM AND OF 4-CHLOROPHENOXYACETIC ACID (4-CPA) AT 15 PPM, APPLIED EITHER AS MIXTURES OR SEPARATELY, AT DIFFERENT TIMES, TO THOMPSON SEEDLESS GRAPES

Treatment	Weight per berry	Pull to remove pedicel*	Degrees Balling	Total acid per cent tartaric
	gm	*gm*		
Girdled on June 6	2.89	383	19.0	0.60
Not girdled, gibberellin, June 6	3.34	321	17.8	0.67
Not girdled, 4-CPA, June 6	2.72	309	19.2	0.64
Not girdled, 4-CPA and gibberellin mixed, June 6	4.09	....	18.9	0.80
Not girdled, 4-CPA, June 6, and gibberellin, June 23	4.20	445	18.0	0.67
Not girdled, gibberellin, June 23	3.39	....	20.9	0.65
L.S.D. at 5 per cent	....	N.S.	....	....

* Average of 80 berries.

The data (table 10, fig. 15) indicate that the greatest increase in berry size resulted when the foliage was sprayed in addition to dipping the fruit. Dipping of clusters alone resulted in about half as much increase in size, while spraying of leaves alone resulted in only about one fourth as much increase in berry size as resulted from treatment of both fruit and foliage. Thus, it is important that the cluster region be thoroughly wetted.

Effect of Gibberellin and 4-CPA. The purpose was to determine the effect on fruit development of gibberellin and 4-CPA applied as a mixture, or of 4-CPA followed by gibberellin at a later date. It had been shown that 4-CPA applied at the shatter stage produced thicker pedicels, resulting in less shat-

Fig. 15. Thompson Seedless clusters 86 days after being sprayed and/or dipped in gibberellin at 25 ppm. (A) untreated; (B) clusters dipped, foliage not sprayed; (C) clusters bagged, foliage sprayed; and (D) clusters dipped and foliage sprayed. Note that largest berries were produced by both dipping of clusters and spraying of foliage (D). Considerable increase resulted from dipping of clusters (B), but only a small increase resulted when only foliage was treated (C). (Photographed September 2, 1958.)

ter at harvest (Weaver and Winkler, 1952). The present experiment sought additional information. On June 6, vines were cluster-thinned to 20 clusters per vine, and berry-thinned. Vines were either trunk-girdled or sprayed with gibberellin at 50 ppm and/or 4-CPA at 15 ppm on June 6, when

shatter of berries was almost completed. Certain lots were again sprayed with gibberellin at 50 ppm on June 23 (table 11). On June 23 many berries sprayed on June 6 with 4-CPA at 15 ppm had pedicels about 30 per cent thicker than those only girdled on June 6. The former berries were 5 to 6 mm wide, the latter, 4 to 5 mm.

Fruit was harvested on September 4. Berries sprayed with gibberellin at the shatter stage (June 6) were large and elongated, while the mixture of 4-CPA and gibberellin on the same date resulted in less elongation. Perhaps both compounds produced a response. Gibberellin applied alone on June 6 or June 23 produced very large berries, although the largest berries were produced by the mixture applied on June 6, or by 4-CPA on June 6 followed by gibberellin on June 23. It may be possible to obtain larger berries by using both regulators than by using either alone. The pedicels were most tightly attached in berries treated by 4-CPA on June 6 followed by gibberellin on June 23, but this finding was not significant.

Black Monukka

In some regions, Black Monukka would be a desirable shipping grape if berries did not shatter easily from the clusters. The effects of gibberellin and 4-CPA on berry size and strength of pedicel attachment were studied

TABLE 12

EFFECT OF GIBBERELLIN AND 4-CHLOROPHENOXYACETIC ACID (4-CPA) ON BERRY WEIGHT AND PEDICEL ATTACHMENT IN BLACK MONUKKA

Condition of vine	Treatment		Weight per berry	Pull to remove pedicel
	Concentration of gibberellin	Concentration of 4-CPA		
	ppm	*ppm*	*gm*	*gm*
Not girdled	..	..	3.09	306
Not girdled	5	..	3.33	276
Not girdled	20	..	4.12	275
Not girdled	50	..	4.01	310
Not girdled	..	15	3.14	348
Girdled	..	..	4.16	386
L.S.D. at 5 per cent	..	..	0.27	N.S.

in this experiment. On June 11, after the shatter of berries, vines were sprayed with gibberellin at 0, 5, 20, or 50 ppm, three vines per treatment. Another series was sprayed with 4-CPA at 15 ppm, and still another was unsprayed but trunk-girdled. A control series was left ungirdled and unsprayed. Fruit was harvested on September 4 (table 12). Gibberellin at 20 or 50 ppm increased weight per berry by about the same amount as girdling, but 4-CPA had little effect (fig. 16). The amount of pull required to remove the pedicel from the berry was less in all spray treatments than in the girdled, although not significantly so (Weaver and Winkler, 1952).

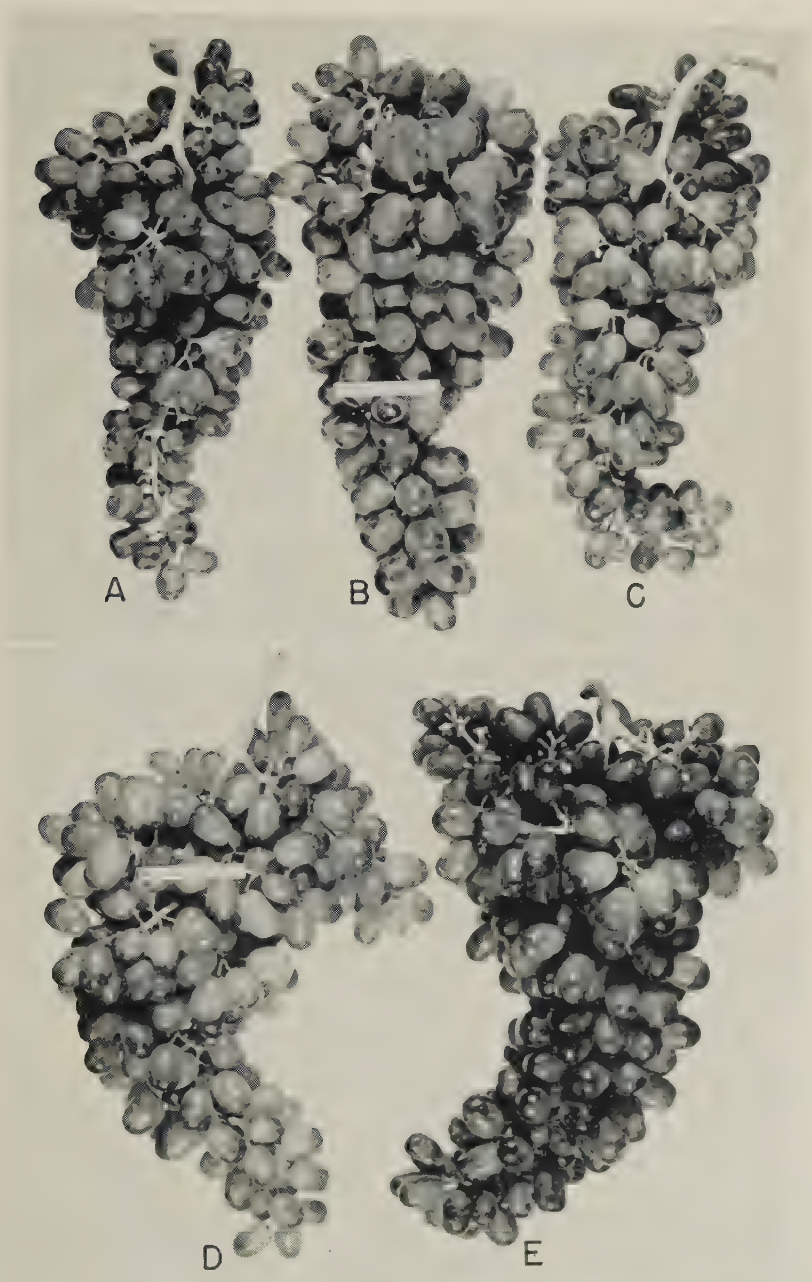

Fig. 16. Clusters of Black Monukka 85 days after girdling or being sprayed with gibberellin at 5 (C), 20 (D), or 50 ppm (E). (A) ungirdled and unsprayed; (B) unsprayed but girdled. Note that both girdling (B) and gibberellin (C, D, E) increased size of berry, but that largest berries resulted from the higher concentrations of gibberellin. (Photographed September 4, 1958.)

DISCUSSION

Berry growth of Black Corinth and Thompson Seedless grapes, as measured by diameter, was in the form of a double sigmoid curve, as has previously been reported for both seeded and seedless *Vitis vinifera* (Winkler and Williams, 1935). These workers obtained a rather smooth double sigmoid curve for Thompson Seedless. Perhaps measurement of berry length or weight would result in a more pronounced plateau on the curve before the final accelerated growth rate or "final swell." Although gibberellin increased size of berry, the general shape of the resulting curve was not altered.

The fact that, when portions of clusters were treated, only the treated berries responded might be expected since the movement of carbohydrate is from the shoots into the berries, and not from berry to berry. Plant regulators usually move in the same direction as the elaborated food materials (Mitchell and Brown, 1946; Weaver and DeRose, 1946). It is difficult to explain, however, why the enlarged, treated berries on a cluster should have a lower percentage of total soluble solids than adjacent, untreated berries in Thompson Seedless.

Time of application of gibberellin to Black Corinth and Thompson Seedless is of prime importance. With Black Corinth, the best time is several days after all calyptras have fallen, because the berries resulting from this treatment are smaller than those resulting from applications at full bloom. Of course, the compounds must be applied before the normal shatter in order not to lose too much crop. The possibility of too large a berry for commercial acceptance may prove a disadvantage of gibberellin in currant production. To increase set in Black Corinth and to increase berry size in Thompson Seedless, the proper time of application for gibberellin coincides with the recommended time for applying 4-CPA for the same purposes (Weaver, 1956).

The fact that gibberellin decreases the berry set in Black Corinth indicates that a reduction in crop may be realized in spite of the larger size of the remaining berries. One advantage of the lower berry count would be a decrease in rotting under certain conditions. This factor might perhaps result in just as much (or more) high-quality fruit as is obtained with 4-CPA, which often produces compact clusters susceptible to rotting.

Black Corinth and Thompson Seedless responded to an even wider range of concentrations than was previously demonstrated (Weaver and McCune, 1958). The best concentration to use would be the lowest that would produce the optimum response, and this must be carefully worked out for various climatic regions.

Why very little gibberellin reached the fruit of Black Corinth through the foliage, and more reached the fruit of Thompson Seedless by this route cannot be explained. With each variety, the cluster region should be thoroughly sprayed to obtain best results. Some field observations on Thompson Seedless showed that the outer berries of sprayed clusters were larger than the inner, which might be explained by assuming that the berries on the inner portion did not receive as much spray. In this connection it should

be mentioned that 4-CPA brought about only slight effects on fruit growth when applied to the leaves of Black Corinth, but marked effects in Thompson Seedless berries when applied only to leaves (Weaver, 1956). Varying degrees of absorption and translocation of gibberellin between varieties, and different physiological stages of vine development probably caused the differences in response.

The fact that the apical portions of young Thompson Seedless clusters made the greatest response, and that the basal portions (peduncle) responded the least is readily explained by the fact that the youngest tissues respond the most to gibberellin. The fact that very young clusters of Thompson Seedless on shoots 2½ to 4 inches long responded less to spray applications of gibberellin than did those at a later date when shoots were 10 to 12 inches long does not necessarily contradict this general observation. It may well be that a greater amount of gibberellin reached clusters of older shoots than of the younger shoots. Perhaps movement of the compound from foliage to clusters was greater at the second spraying.

Until the advent of gibberellin, flower cluster thinning (removal of a portion of the clusters from a vine) was the only known method of increasing cluster length (Winkler, 1931). This, however, had the definite disadvantage of improving berry set.

Prebloom sprays of gibberellin on Thompson Seedless hastened flowering in the same manner as previously reported (Weaver and McCune, 1958), but the evidence is not yet conclusive that such sprays hastened maturation, since crop levels were usually too irregular to be eliminated as factors affecting the rate of maturation. The effects of prebloom sprays on elongating cluster parts in Thompson Seedless were rather small when measured at harvest time, indicating that this variety is rather insensitive to gibberellin in so far as elongation of cluster is concerned. It may be that Thompson Seedless clusters contain sufficient amounts of naturally occurring gibberellin for almost maximum elongation, perhaps indicated by the varietal characteristic of the long cluster and oval berry.

Thompson Seedless berries were much larger at Davis in 1958 than in 1957 (Weaver and McCune, 1958). This may account for the fact that there was much less response to gibberellin in 1958 (Weaver and McCune, 1958).

SUMMARY

The response of Black Corinth, Thompson Seedless, and Black Monukka seedless varieties of *Vitis vinifera* to gibberellin was studied in 1958 at Davis, California.

The berry-growth curves of Black Corinth and Thompson Seedless were double sigmoid when cumulative growth increments in diameter were plotted. Gibberellin applied shortly after bloom increased berry diameter, but did not alter the general shape of the growth curves.

When portions of Black Corinth or Thompson Seedless clusters were treated with gibberellin, only the treated portions responded to the compound. However, when one portion of a berry was treated, the whole berry responded in the same manner as if the whole berry had been treated. In

Thompson Seedless, the enlarged, treated berries on a cluster had a lower Balling reading than did the adjacent, smaller, untreated berries.

Black Corinth clusters dipped in gibberellin one week before inception of bloom, at bloom, and after calyptras had fallen showed that the largest berries resulted from the treatment at bloom. The number of berries per cluster was decreased by all treatments, and only slight elongation of cluster parts was obtained.

In Black Corinth, increasing concentrations of gibberellin from 1 to 100 ppm usually progressively increased berry size and length-to-width ratio. 4-CPA resulted in almost round, small berries about the same size as those from girdled vines.

An experiment in which foliage and/or clusters of Black Corinth were treated with gibberellin at 25 ppm demonstrated that little increase in size of berry resulted from compound absorbed by the leaves.

The percentage increase in length of young Thompson Seedless clusters dipped in gibberellin was greatest in the apical portion and least in the basal (peduncle).

Thompson Seedless vines were sprayed with gibberellin at 10, 25, or 50 ppm on April 15, April 28, May 9, or May 19, all prebloom stages. Length of cluster was increased by the second spray application. Weight of fruit was sometimes decreased by gibberellin, but of four instances where crop level could be eliminated as a factor, two treatments showed significant increases in percentage of total soluble solids.

Two Thompson Seedless vines were sprayed with gibberellin at 50 ppm on April 28 to elongate cluster parts. On June 11, after the shatter of berries, some canes were girdled, and clusters on other canes were dipped in gibberellin at 50 ppm. Both dipping and girdling increased berry size.

Gibberellin at 1 ppm, applied after shatter, increased berry size of Thompson Seedless, and higher concentrations usually produced progressively larger berries. The compound at 1,000 ppm injured the berries, but foliage and shoots were uninjured. The largest berries were produced by combined gibberellin and girdling.

Largest berries were produced in Thompson Seedless by spraying on June 2 or June 7, and later sprayings produced progressively smaller berries. Berries from vines sprayed on July 29 were only slightly larger than the unsprayed berries.

Thompson Seedless vines bearing 16, 32, or 48 clusters per vine all responded to applications of gibberellin at 20 ppm, applied on June 6 (berry-shatter stage), by producing larger berries.

When level of crop was eliminated as a factor by suitable thinning, it was found that gibberellin sprays applied on June 5 had no significant effect on Balling reading.

A greater increase in size of Thompson Seedless berries resulted from spraying foliage and dipping clusters in gibberellin than from treating only leaves or clusters. Gibberellin absorbed by the leaves had only a small effect on enlarging the fruit.

Gibberellin and 4-CPA were applied either separately or as a mixture,

to Thompson Seedless on June 6. Another series was treated with 4-CPA on June 6 and with gibberellin on June 23. The largest berries resulted from the mixture applied on June 6 and the 4-CPA applied on June 6 and followed by gibberellin on June 23. The pedicels were perhaps more tightly attached in clusters that received the latter treatment.

Gibberellin applied on June 11 at 20 or 50 ppm increased berry size of Black Monukka about the same amount as did girdling, but 4-CPA at 15 ppm had little effect. The amount of pull required to remove the pedicel from the berry was less in all fruit from vines receiving spray treatments than in those from the girdled vines, but not significantly so.

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